X-Ray Machine & Production

Prepared by

Prof. Eman Abd Elaziz Ahmed

The X-Ray Machine

The dental x-ray machine consists of three visible component parts:

1. The control panel
2. The extension arm
3. The tubehead

I. ***The control panel*** of the dental x-ray machine contains an on-off switch and an indicator light, an exposure button and an indicator light, and control devices (time, kilovoltage, and milliamperage selectors) to regulate the x-ray beam.

II. ***The extension arm*** suspends the x-ray tubehead and houses the electrical wires that extend from the control panel to the tubehead. The extension arm allows for movement and positioning of the tubehead.

III. Tubehead:

The x-ray tubehead is a tightly sealed, heavy metal housing that contains the x-ray tube that produces dental x-rays. The component parts of the tubehead include the following:

a. The x-ray tube (main part)
b. Transformers
c. Insulating oil
d. Metal housing.
e. Accessories (filter, collimator and cone)

A . X-ray tube:

- It is an evacuated tube of glass with two electrodes extending in two opposite directions which are the cathode and anode.

- *The tube is evacuated to:*
  1) Prevent collision of the moving electrons with the molecules of air ------ preserve their energy.
  2) Prevent oxidation and burn out of the filament.

- It is usually a leaded-glass tube that prevents x-rays from escaping in all directions. It has a window that permits the x-ray beam to exit the tube and directs the x-ray beam toward the aluminum disks, lead collimator, and cone.

X-ray tube components:

- Cathode
- Anode

- **Cathode:**

It is the (-ve) electrode of the tube which serves as source of electrons.
The cathode is composed of:

1. Tungsten filament:

- It is a coil of tungsten wire. Tungsten is chosen because:
  a. It has a very high melting point.
  b. It has a high atomic number, which denoting ↑↑ no. of protons →↑↑ no. of electrons → good source of electrons.

2. Focusing Cup:

- It is made of molybdenum. It is a negatively charged concave reflector cup. This cup collects the electrons and repels them till they are attracted by the anode.

- **Anode:**

The anode is the (+ve) electrode of the tube. It is composed of target, copper head and copper arm.

1. Target:

It is also made from tungsten because:

- It has a high atomic number (74); as materials of high atomic number are more efficient in production of x-rays.
- It has a high melting point.
- It has insufficient thermal conductivity.
- ***The focal spot*** is the area on the target onto which the focusing cup directs the electrons from the filament.

2. Copper head:

- Because of the poor thermal conductivity of the tungsten target, it is embedded in a copper head to dissipate the heat which accompanies the process of x-ray production.

3. Copper arm:

- It extends out of the copper head, outside the glass tube and connected to step –up transformer.

The power supply of x-ray machine:

The primary function of the power supply is to provide:

- A current to heat the filament.
- A potential difference between the cathode and anode.

B. Transformers:

A transformer is a device that is used to either increase or decrease the voltage in an electrical circuit. In the production of dental x-rays, three transformers are used to adjust the electrical circuits:

1. Step-down transformer:

It is connected to the filament of the cathode. It reduces the voltage of the incoming current from 220 volt → 8-12 volt, which is sufficient to heat the filament → cloud of electrons.

2. Step-up transformer:

It is connected to the copper arm of the anode, and raises the volt from 8-12 volt → 65-75 kilovolt or even more.

3. An autotransformer serves as a voltage compensator that correct for minor fluctuations in the current.

C.The insulating oil, or the oil that surrounds the x-ray tube and transformers inside the tubehead; it prevents overheating by absorbing the heat created by the production of x-rays.

D. The metal housing:

The metal housing is made of lead and it surrounds the glass tube (with its cathode and anode), the insulating oil and transformers. The metal housing will absorb all the rays coming out of the generating system except the useful beam.

E. Accessories:

- Filter
- Collimator
- Cone

(1) Filter:

- The x-ray beam is a heterogeneous beam containing rays with longer and shorter wave lengths. The filter will remove rays with longer wavelength and have ↓↓ power of penetration.

Types of filter:

- Added filters
- Inherent filters

A. Added filters:

These are thin sheets of aluminum placed at the aperture of x-ray tube in order to improve the quality of the beam.

They are external filters that can be removed or added. Their thickness differs and varies according to the kvp of the x-ray machine.

B. Inherent filters:

They include any material that the x-ray photons encounter as they pass from the target to outside.

1. Glass wall of x-ray tube

2. Insulating oil
3. The barrier material that prevents the oil from escaping through the x-ray port.

The total filtration of x-ray tube = added + inherent

The total filtration in the path of a dental x-ray beam is equal to the equivalent of:

1.5 mm Al ⟶ with KV up to 70 KVP

2.5 mm Al ⟶ with KV ↑ 70 KVP.

(2) Collimator:

It is a device used to restrict the size of x-ray beam just to cover the film to produce the desired image ($2^3/_4$ inches in diameter).

The interactions between the primary beam and the atoms of the objects → production of secondary radiation (or scattered radiation) → ↑↑ surface area to be irradiated and can also reach the film → ↓↓ image quality. So, by collimators →↓↓ effect of scattered rays →↓↓ patients' exposure and ↑↑ image quality.

Types:

- Diaphragm collimator: It is a thin plate of lead with central hole.
- Tubular collimator: It is a tube of lead with a diaphragm connected to one of its ends.
- Rectangular collimator.

(3) Cones: **[**Position Indicating Device (PID)]

It is a device used to fix the target- film distance, to indicate the point of entry and to delineate the direction of x-ray beam.

Classification:

a) According to composition:

- Plastic or glass cone.
- Metallic: specially lead which can acts as both collimator & cone (it is very heavy).

b) According to shape:

- Open end (cylindrical) cone:

It is more preferable because the x-ray beam will not strike the cylindrical walls which are in accordance with the almost parallel rays except for the few diverging rays (the scattered radiation results from interaction with the wall).

- Pointed end or conical cone:

It has a very harmful effect since it acts as a source of scattered radiations as the rays will hit the walls.

c) According to length:

- Short cones 8"
- Long cones 16"

} They are used according to the radiographic technique

Timer:

It is a device which control the exposure time and is calibrated in fraction of seconds.

Types:

a) *Automatic timers:*

- Direct or immediate timers:

They are attached to a long cord to enable the operator to move away from the field of radiation.

- Delayed timers:

They are cordless timers. They provide a period of 7-9 seconds to enable the operator to move away from the field of radiation.

b) *Manual timers:*

- The exposure is controlled manually.
- Those timers existing on older machines are imprecise when used for the short exposures.

Production of x-rays

Principle:

When an electric current pass through a filament or wire → heating of the filament → the orbiting electrons within its atoms will be more energetic, some will acquire sufficient energy→ escape from their shells → cloud of electrons.

If these electrons are accelerated then suddenly stopped, their kinetic energy will be converted into heat + x-rays.

Procedure:

- When the x- ray machine is turned on, the electric current enters the control panel via the cord plugged into the wall outlet. The current travels from the control panel to the tubehead via the electrical wires in the extension arm. The step-down transformer reduces the 220 entering line voltage to 8 to 12 volts.
- This current is sufficient to heat the filament of the cathode and produce electrons; their number is directly proportional to the degree of heating (by thermionic emission).
- The cloud of electrons formed around the cathode will be collected by the focusing cup.

- When the exposure button is pushed, a step-up transformer which is connected to the anode will ↑↑ the potential difference between the anode & cathode by ↑↑ the volt into 65-70 KV or even more.
- As a result, the cloud of electrons will be accelerated to move towards the anode. When the electrons strike the tungsten target, their energy of motion (kinetic energy) is converted to x-ray energy and heat. Less than 1% of the energy is converted to x-rays; the remaining 99% is converted into heat.

Thermionic emission:

Thermionic emission is the release of electrons from the tungsten filament when the electric current passes though it and heats it up.

Types of X-Rays:

Not all x-rays produced in the x-ray tube are the same; x-rays differ in energy and wavelength. The energy and wavelength of x- rays vary based on how the electrons interact with the tungsten atoms in the anode. The kinetic energy of the electrons is converted to x-ray photons via one of two mechanisms:

1. Bremsstrahlung radiation.
2. Characteristic radiation.

Terminology

Term	Definition
Primary radiation	Radiation coming directly out of the target in all direction and most of them is absorbed by the tube housing except for the useful beam.
Useful beam	It is a part of primary radiation, which is not absorbed by the housing but passes through the aperture and affect the film.
Secondary radiation	Radiation that generated from the patient, surrounding objects due to passage and interaction of the primary beam with these objects. It is of longer wavelength and lower energy than primary radiation.
Soft radiation	Radiation produced by low Kv, are of longer wavelength, low energy, low penetration power, high absorption and have a more damaging effect.
Hard radiation	Radiation produced by high Kv, are of short wavelength, high energy, high penetration power, low absorption and of diagnostic value.

Scattering	Change in direction of a photon with or without a loss of energy.
Absorption	Deposition of energy, i.e removal of energy from the beam.
Attenuation	Reduction in the intensity of the main x-ray beam caused by absorption and scattering.
Ionization	Removal of an electron from a neutral atom producing a negative ion and a positive ion.

References:

1. Eric Whaites & Nicholas Drage. Essentials of dental radiography and radiology, 6th edition. Elsevier, Churchill Livingstone, 2020.

2. Eric Whaites & Nicholas Drage. Essentials of dental radiography and radiology, 5th edition. Elsevier, Churchill Livingstone, 2013.

3. Joen M. Iannucci & Laura Jansen Howerton. Dental radiography: Principles & Techniques. 6th edition. Elsevier, Saunders, 2022.

4. Stuart C. White & Michael J. Pharoah. Oral radiology: Principles and interpretation, 7th edition. Elsevier, Mosby Inc., 2014